RESEARCH DEPARTMENT

VERTICAL APERTURE CORRECTION WITH MINIMAL INCREASE IN NOISE

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SUMMARY

Vertical aperture correction of a television signal can be achieved by combining the signal from each scanning line with suitably-weighted proportions of the signals from the preceding and succeeding lines in the same field. Vertical aperture correction gives a significant improvement in the vertical resolution of a picture but normally results in a reduction in the signal-to-noise ratio. This report discusses methods of reducing the loss of signal-to-noise ratio associated with vertical aperture correction.

1. INTRODUCTION

A practical method of vertical aperture correction was first proposed by W.G. Gibson and A.C. Schroeder of R.C.A.;[1] the block diagram of a suitable circuit[2] is shown in Fig. 1. The improvement in vertical resolution is achieved by subtracting, from the signal corresponding to each main scanning line,* equal proportions of the signals corresponding to the preceding and succeeding lines. The circuit of Fig. 1 is arranged so that a correction signal is obtained which comprises a positive contribution from the main scanning line in addition to negative contributions from the preceding and succeeding scanning lines. The addition of a component from the main scanning line results in a correction signal that is zero except in those areas where vertically-adjacent points on successive scanning lines carry differing information; thus the mean picture brightness is unaltered by the addition of the correction signal. The addition of the correction signal results, however, in a relative increase of any noise present in the input signal so that the signal-to-noise ratio is reduced.[3] For example, in those areas of the picture where the correction signal ought to be zero, the noise components corresponding to vertically-adjacent points on successive scanning lines are virtually uncorrelated and thus contribute to the noise present in the output of the corrector.

In practice, the signal-to-noise ratio of a camera picture may be marginal and, in such a case, the vertical resolution of the picture cannot be improved by

* For convenience, the scanning line to which correction is being applied is referred to as the 'main scanning line' in order to avoid confusion with the preceding and succeeding scanning lines, which are used in producing the correction signal.

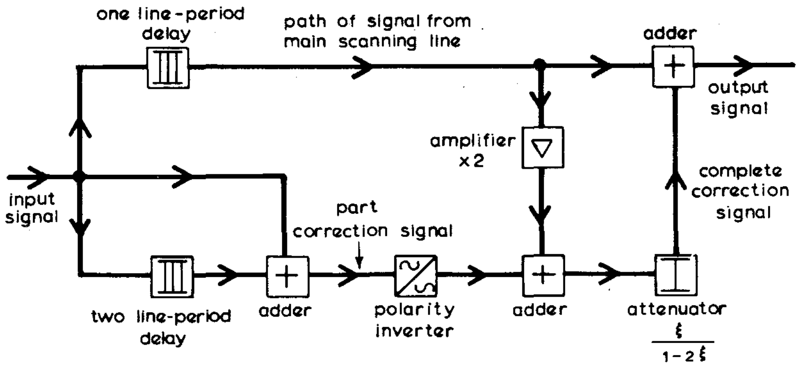

Fig. 1 - Block schematic of a vertical aperture corrector

vertical aperture correction without a significant impairment of picture quality due to the reduction in signal-to-noise ratio, unless horizontal aperture correction is reduced at the same time. Three proposals have been made of methods whereby the loss of signal-to-noise ratio due to the use of vertical aperture correction could be reduced and their usefulness is discussed in this report.

2. METHODS OF REDUCING THE LOSS OF SIGNAL-TO-NOISE RATIO

2.1. Bandwidth Restriction of the Complete Correction Signal

Gibson and Schroeder[1] have proposed the use of a low-pass filter to restrict the bandwidth of the correction signal and thus to reduce the magnitude of the noise accompanying the corrected signal; the arrangement is illustrated in Fig. 2. However, the resulting improvement in the signal-to-noise ratio of the corrected signal is accompanied by a loss of vertical aperture correction for vertical picture detail corresponding to video frequencies above the cut-off frequency of the filter; such detail includes sloping lines and edges.

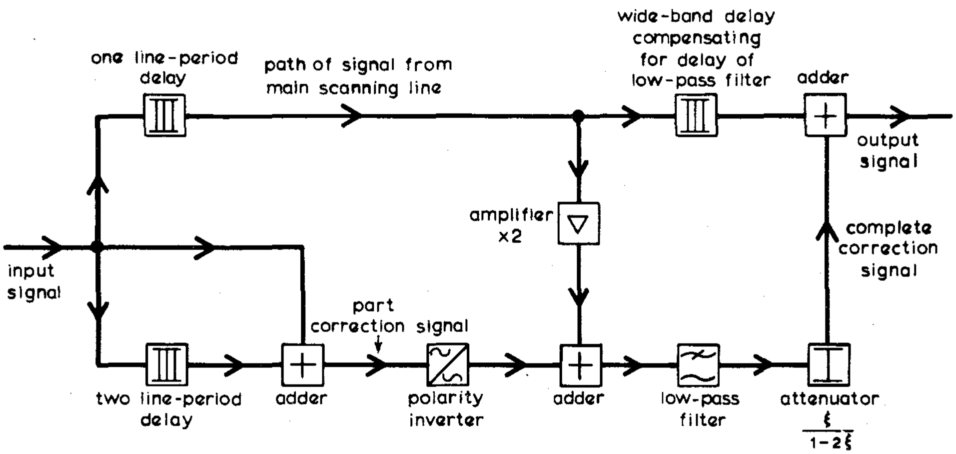

Fig. 2 - Vertical aperture corrector with bandwidth restriction of the complete correction signal

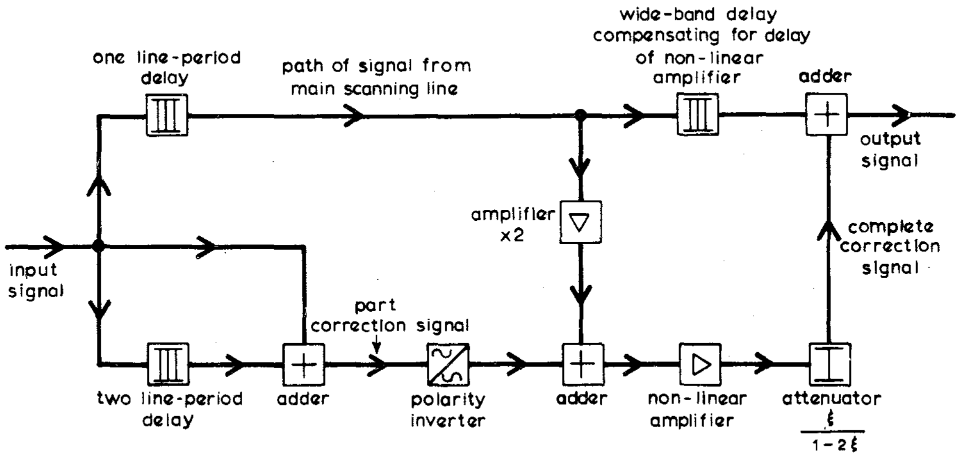

Fig. 3 - Vertical Crispener

2.2. Vertical Crispening

It has been suggested that the signal-to-noise ratio, in those areas of the corrected picture where vertically-adjacent points on successive scanning lines carry identical information, could be improved by the insertion of a non-linear amplifier in the path of the complete correction signal,* as illustrated in Fig. 3 and Fig. 6. This process may be termed 'vertical crispening' in view of its resemblance to non-linear processes termed 'crispening' which have been used to improve the horizontal resolution. The reduction of noise by this arrangement can be considerable; for example, it can be shown that if the non-linear amplifier is arranged so that noise whose peak-to-peak magnitude does not exceed six times its r.m.s. value is suppressed, the r.m.s. value of the noise will be reduced by approximately 97%. It must, however, be noted that the non-linear amplifier will be unable to distinguish between random noise and picture signals of comparable magnitude. Thus, as well as reducing the noise level, the use of a non-linear amplifier results in a loss of vertical

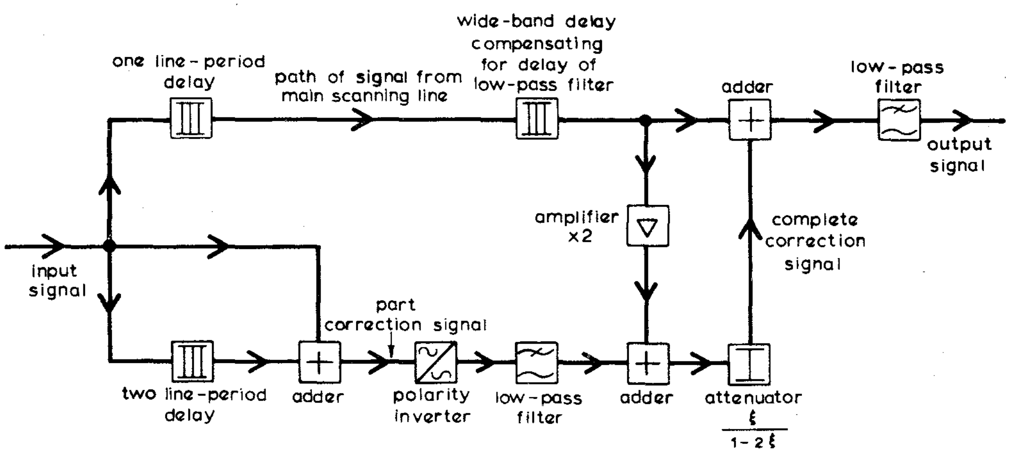

Fig. 4 - Vertical aperture corrector with bandwidth restriction of part of the correction signal

* This method was proposed by Mr. G.F. Newell, formerly of BBC Research Department

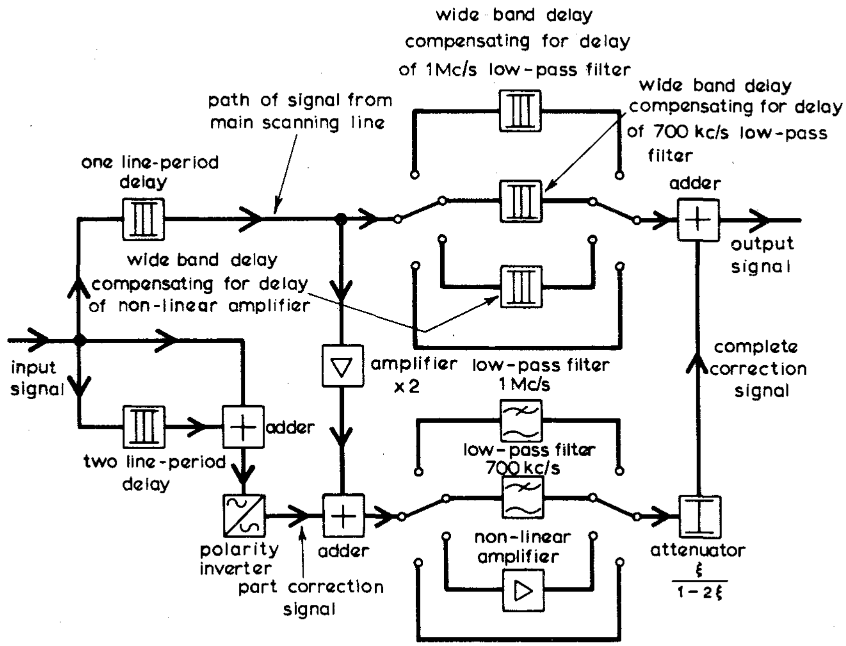

Fig. 5 - Experimental arrangement used for the tests

aperture correction in those picture areas where there is only a small difference between the signals corresponding to vertically-adjacent points on successive scanning lines (e.g. at low-contrast horizontal boundaries). The advantage in signal-to-noise ratio is therefore gained at the expense of some picture impairment and it is unlikely that a substantial advantage could be gained if the signal-to-noise ratio before correction were very low.

2.3. Bandwidth Restriction of Part of the Correction Signal

An arrangement is shown in Fig. 4 in which the noise in the corrected output signal is reduced by inserting a low-pass filter in the path of the correction signal at a point before that at which a proportion of the signal from the main scanning line is added. However, with this arrangement the response/frequency characteristic of the output signal rises at the higher video frequencies. The higher video frequencies can therefore be attenuated and this attenuation results in a reduction of noise; however, the improvement in signal-to-noise ratio is accompanied by an impairment of the vertical resolution of the corrected signal at the higher video frequencies. It can be shown, however, that after attenuation of the higher video frequencies, the improvement of signal-to-noise ratio is identical with that obtained with the arrangement of Fig. 2.

3. SUBJECTIVE MEASUREMENTS

It was decided that the arrangements involving bandwidth restriction of the complete correction signal (shown in Fig. 2) and the insertion of a non-linear amplifier in the complete correction signal (shown in Fig. 3) should be tested experimentally. The arrangement used for the tests is shown in Fig. 5 and it incorporated two filters having Gaussian response/frequency characteristics with 6 dB attenuation

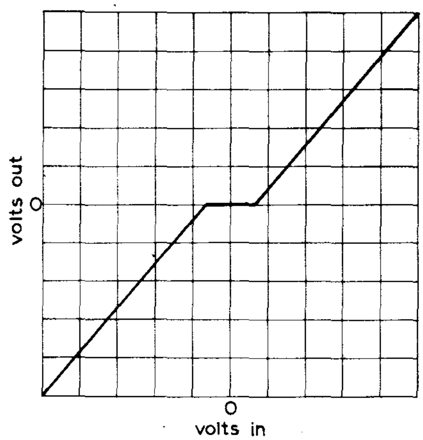

Fig. 6 - Law of non-linear amplifier

points of 700 kc/s and 1 Mc/s, a non-linear amplifier, and a 'straight through' path enabling the corrector to be used in its unmodified form (i.e. as in Fig. 1). The response of the non-linear amplifier used in the tests is illustrated in Fig. 6. The signal level below which the non-linear amplifier provided complete suppression was adjusted in the tests to give a compromise between reduction in noise and impairment of the vertical resolution.

The tests were conducted using an input signal, derived from a slide scanner whose signal-to-noise ratio was 38 dB. This signal-to-noise ratio approximates to that of an average 4½ in. image orthicon camera, although the noise spectrum and distribution of noise in the grey scale will be somewhat different. If the signals corresponding to the main scanning line and the preceding and succeeding lines are denoted by e_1, e_2 and e_3 respectively, the corrected signal may be written:

$$e_1 - \xi(e_2 + e_3)$$

where ξ is the calibration factor.[2,3] Values of the calibration factor of 0, 0·1 and 0·167 were used. A group of five technical observers compared the pictures derived from the output of the vertical aperture corrector with uncorrected pictures; the corrected pictures were assessed according to the subjective scale shown in Table 1. The comparisons were made for noise, picture sharpness and overall picture quality and the pictures used were Test Card 'C' and a slide representing an interior view of a studio which contained considerable horizontal and near-horizontal detail.

TABLE 1 : Comparison scale used for subjective tests

+3	Much better
+2	Better
+1	Slightly better
0	The same as
-1	Slightly worse
-2	Worse
-3	Much worse

4. RESULTS OF SUBJECTIVE MEASUREMENTS

The results of the subjective comparisons are shown in Figs. 7 and 8. Each point on the graphs is the average of the opinions of the five observers. Figs. 7(*i*),

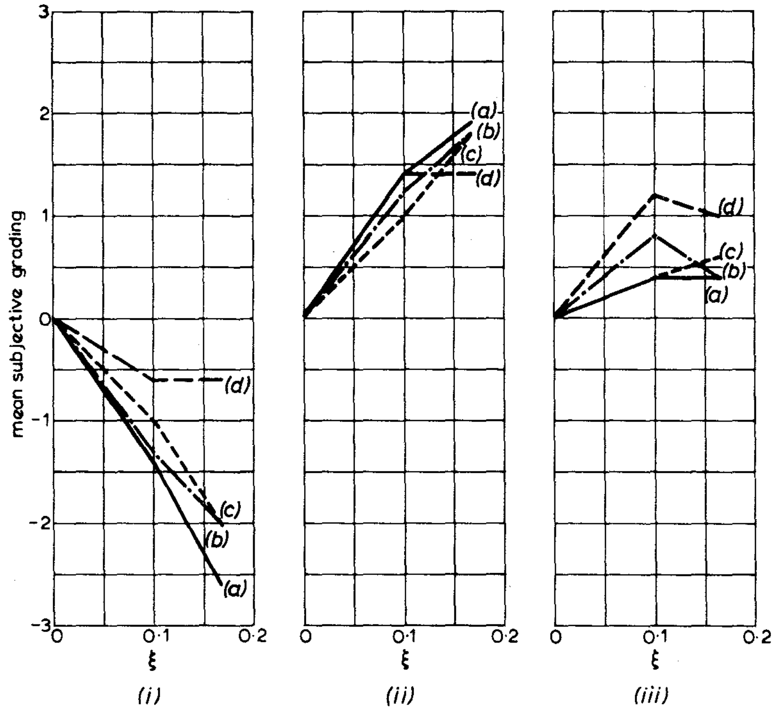

Fig. 7 - Subjective effect of vertical aperture correction on Test Card 'C'

Input signal-to-noise ratio : 38 dB

A positive value shows that vertical aperture correction produced a subjective improvement

(a) Unmodified corrector *(b)* 1 Mc/s bandwidth for correcting signal
(c) 0·7 Mc/s bandwidth for correcting signal *(d)* Vertical crispener

(i) Noise *(ii)* Sharpness *(iii)* Overall picture quality

7(*ii*) and 7(*iii*) show the results of comparisons between the corrected and uncorrected versions of Test Card 'C' with increasing vertical aperture correction from the points of view of noise, picture sharpness and overall picture quality respectively. Each figure comprises four graphs, corresponding to:

(a) An unmodified vertical aperture corrector (as illustrated in Fig. 1)

(b) A vertical aperture corrector with bandwidth restriction of the complete correction to 1 Mc/s (as illustrated in Fig. 2).

(c) A vertical aperture corrector with bandwidth restriction of the complete correction to 700 kc/s (as illustrated in Fig. 2).

(d) A vertical crispener (as illustrated in Fig. 3).

It will be seen in Fig. 7(*i*) that the impairment of signal-to-noise ratio which accompanies increasing vertical aperture correction is significantly reduced only in the vertical crispener. Fig. 7(*ii*) shows that the subjective improvement of

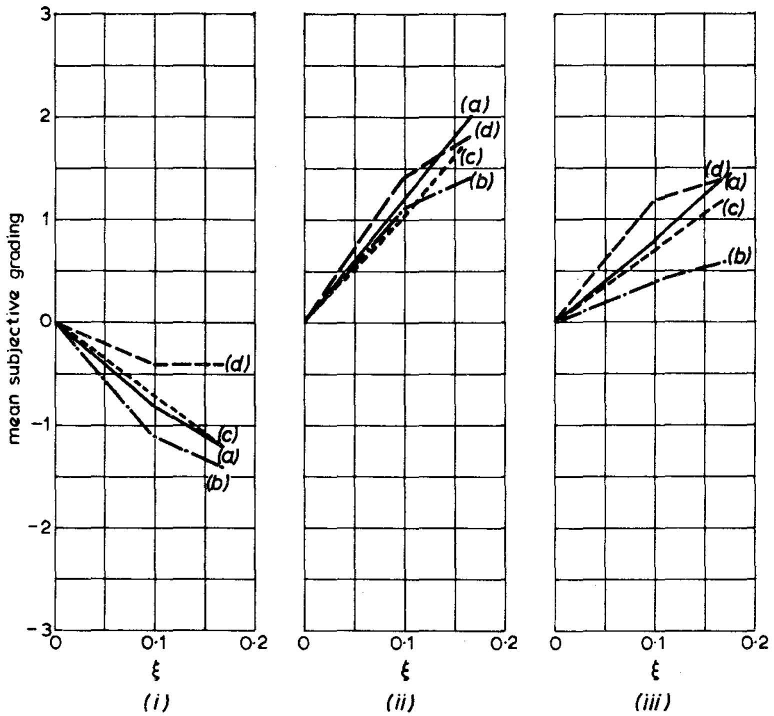

Fig. 8 - Subjective effect of vertical aperture corrector on a still picture

Input signal-to-noise ratio : 38 dB

A positive value shows that vertical aperture correction produced a subjective improvement

(*a*) Unmodified corrector (*b*) 1 Mc/s bandwidth for correcting signal
(*c*) 0·7 Mc/s bandwidth for correcting signal (*d*) Vertical crispener

(*i*) Noise (*ii*) Sharpness (*iii*) Overall picture quality

picture sharpness with increasing vertical aperture correction is not significantly reduced by any of the arrangements tested. If noise is the predominant impairment, Fig. 7(*iii*) confirms the results of Fig. 7(*i*) since the picture quality given by the arrangement of Fig. 3 is better than that of the other three arrangements tested.

Fig. 8 is similar to Fig. 7 and summarises the results of tests using the studio scene. It will be seen that the results confirm those shown in Fig. 7 for Test Card 'C'.

It is not surprising that little improvement in noise was obtained using the arrangement of Fig. 2 since it is known that high frequency noise is less visible than low frequency noise.[4] Nevertheless, it should be noted that if the picture source generated triangular noise (as for example would a vidicon or plumbicon camera) the arrangement of Fig. 2 would offer a greater advantage that that shown in the tests. It is improbable, however, that the reduction in noise would approach that given by the vertical crispener. It is worth noting that the circuit of Fig. 2 would be useful if it were required to apply vertical aperture correction to a composite NTSC colour signal. The colour subcarrier is reversed in phase on successive lines of a

field and, if the unmodified arrangement of Fig. 1 is used, the level of the subcarrier will be enhanced. Thus the chrominance/luminance ratio of the signal will be changed. Suppose, however, that the arrangement of Fig. 2 is used and the low pass filter is arranged to give a high attenuation at the colour subcarrier frequency. Vertical aperture correction will not now be applied at the subcarrier frequency and the chrominance/luminance ratio of the composite signal will be unchanged.

5. CONCLUSIONS

In this report three modified forms of vertical aperture corrector are described which are designed to reduce the increase in noise resulting from the use of vertical aperture correction. Two of the modified forms of vertical aperture corrector have been tested experimentally and the results of the tests show that a vertical crispener (the system which involves the inclusion of a non-linear amplifier in the correction-signal path) offers a worthwhile improvement in performance. The use of the non-linear amplifier significantly reduces the increase in noise without causing any significant reduction in picture sharpness.

6. REFERENCES

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